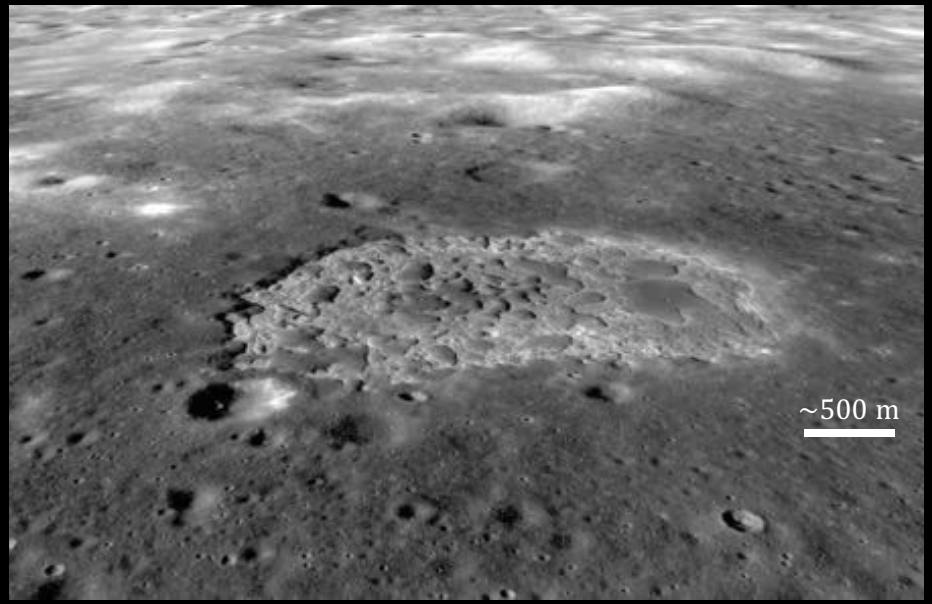
Exploring Lunar Volcanism: Unique Mare Basalt Sites

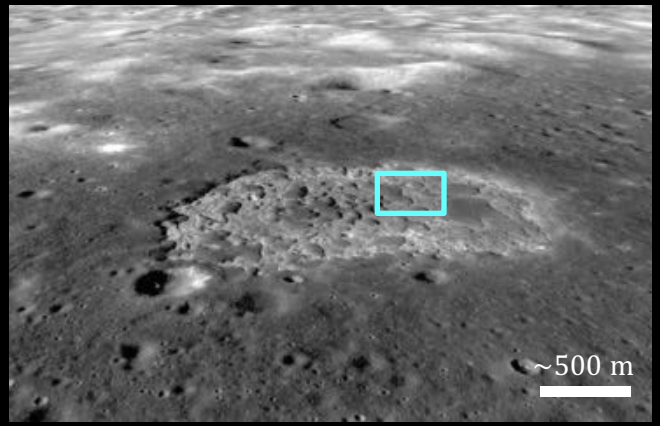
Ina Caldera



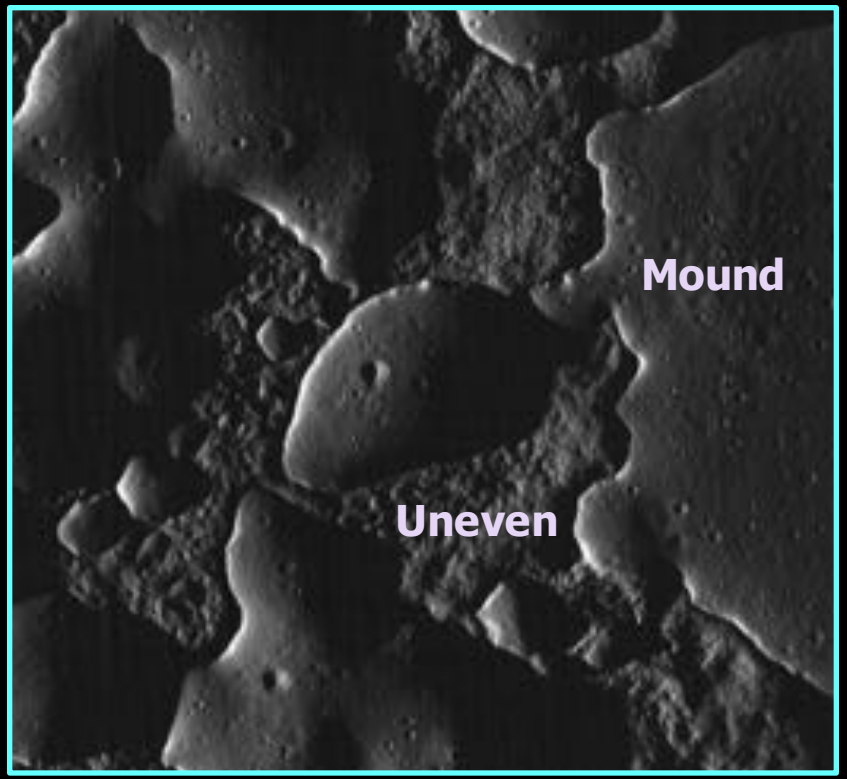
Marius Hills Volcanic Complex

Stopar J. (Lunar & Planetary Institute)
Lawrence S.J. (NASA JSC) • **Speyerer E.J.** (Arizona State Univ.)
Draper D. (NASA JSC) • **Denevi B.W.** (JHU-APL)

Ina Caldera – Landform Morphology



3D perspective view



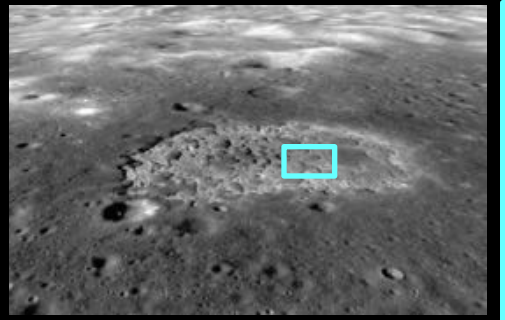
Nadir

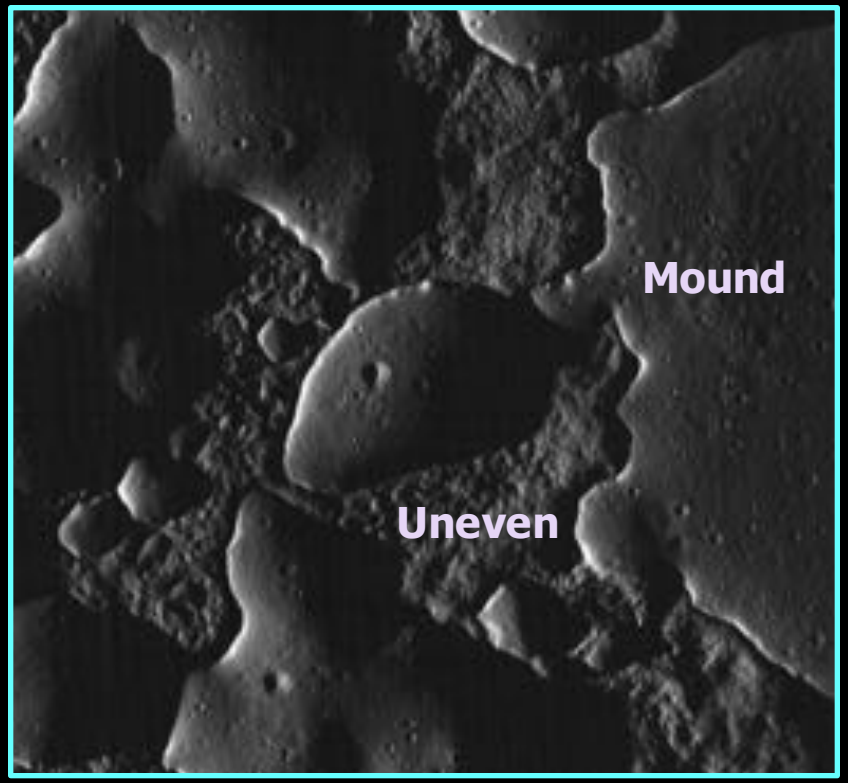
150 m

Uneven: low-relief (m-scale) materials with hummocky, pitted, or ropy textures

Mound: smooth mounds (<20 m high) with steep margins (>45°)

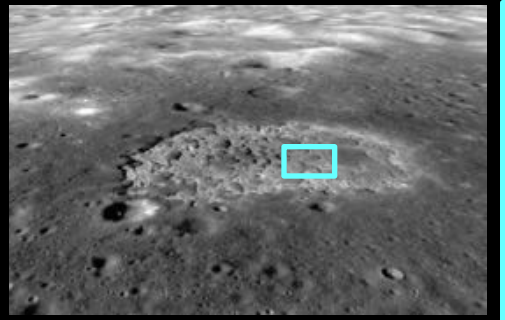
Ina Caldera – What we think we know

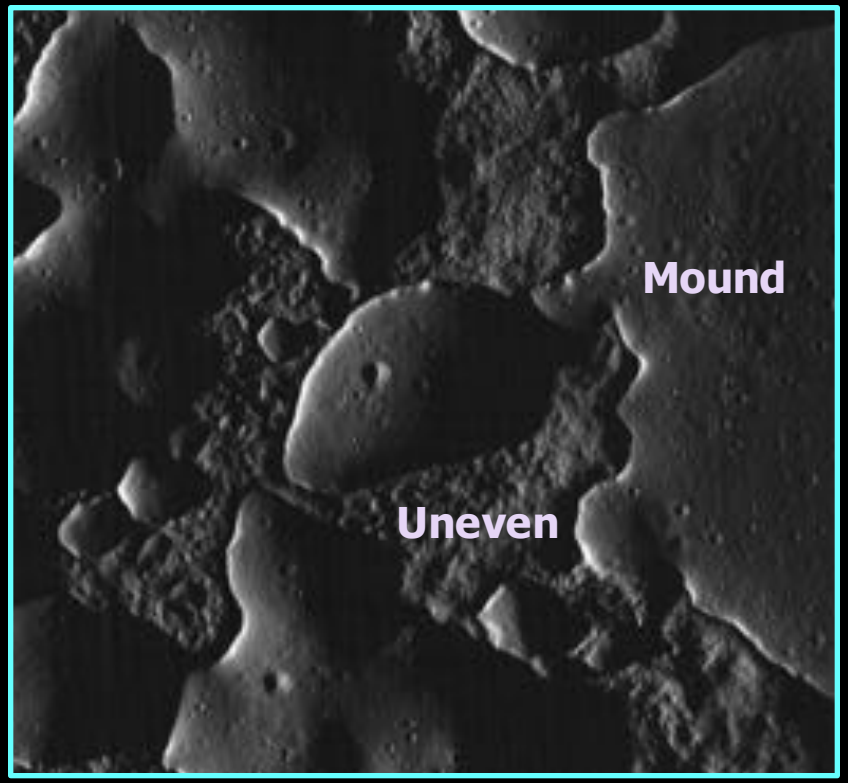




- Volcanic emplacement for mounds and uneven materials
- Mounds and uneven materials have not undergone heavy or even moderate degradation
- There is a >5cm coating of fine particulate materials or regolith (Elder et al. 2017)

Ina Caldera – Geologic Enigma

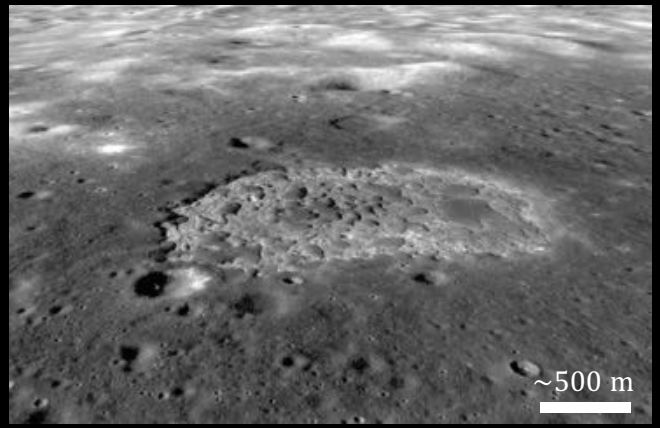




Open Questions:

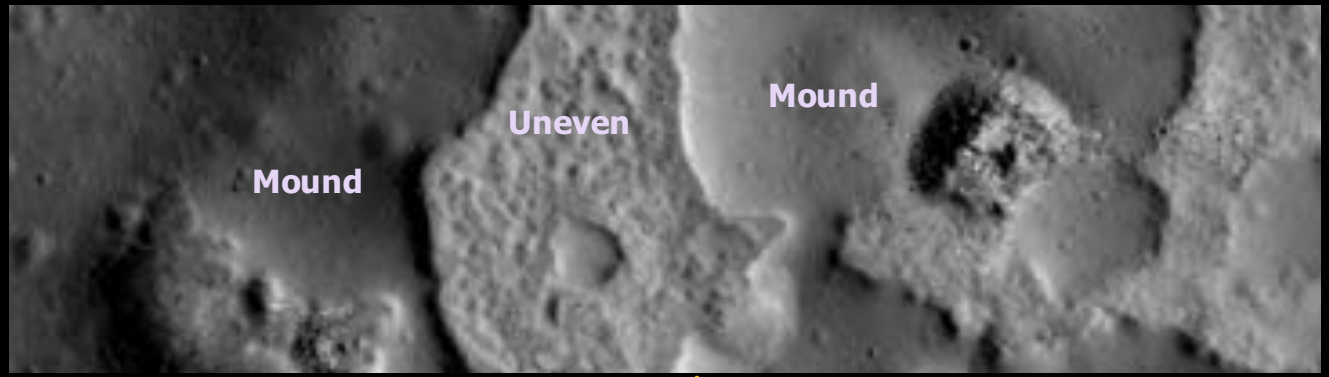
- What came first – mounds or uneven deposits?
- What are they made of – residual vent materials? Highly vesiculated basalts in a lava pond/lake setting, or something else?
- When where they deposited – are they ancient (3.5 Ga) or relatively young (100 Ma or even more recent)?

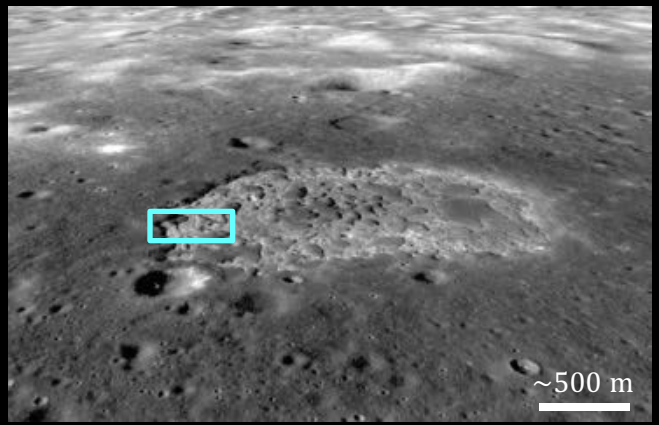
Ina Caldera – Traceability & Science Objectives



Traceability to Goals	Science Objectives	Key Measurements
Investigate range, flux, and diversity of basaltic volcanism (Decadal, SCEM, NASA's strategic plan)	Are sub-meter scale fractures typical of volcanic deposits present? (evidence of volcanic lava flows?)	• High resolution imaging (improve on current best available) • High resolution compositional information (look at contacts between deposits) • High resolution geo-mechanical information (surface materials and as exposed along outcrops)
	Are sub-meter scale collapse pits present? (any evidence of extensive erosion?)	
	What is the composition? (type of lava flow, pyroclastics?)	
	What are the physical properties of surface materials? (grain size, vesicularity/porosity, strength/cohesiveness, maturity and thickness of regolith)	
	What is (are) the age(s) of the deposits?	

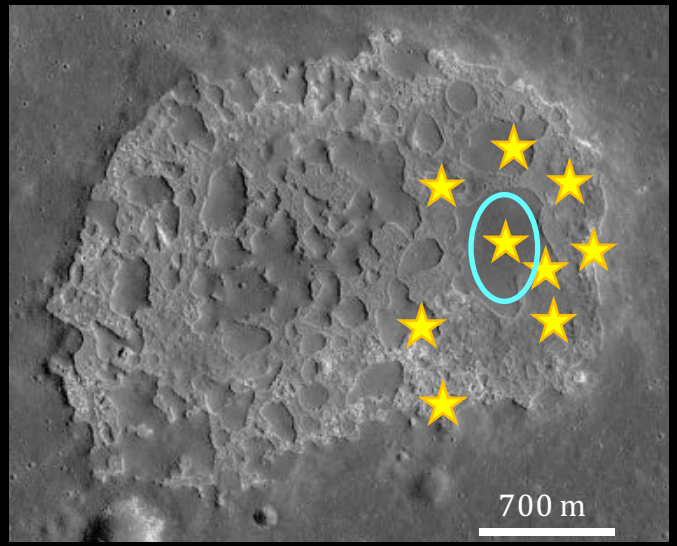
Ina Caldera – Case for a Lander





- The small area (~7 km^2) and small scale of the surface deposits require surface access and in situ investigations
- For example, sharp contacts between deposits are less than a few to 10 m across, and many details exceed the currently available best resolution of 0.4 m/pix
- A focused, surface investigation such as a lander can address many specific science objectives
- Although, a rover or sample return could enhance science return

Ina Caldera – *IMPEL* SmallSat Mission Concept



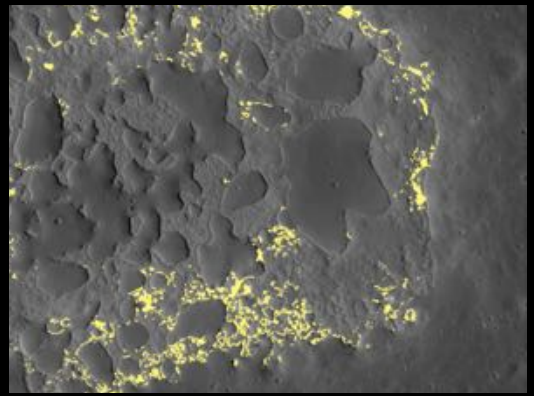
Nadir

Targeted landing site

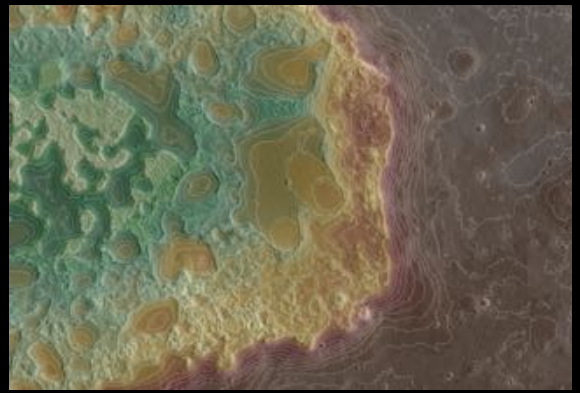
High-priority visible targets for observations

IMPEL (Irregular Mare Patch Exploration Lander)

- Targeted landing on largest mound in Ina
- Lander is 97x97x137 cm, with top-mounted pan/tilt camera system inspired by Mastcam
- Upon landing, *IMPEL* would collect panoramas and targeted images of mounds, uneven materials, and outcrops
- Examples of these materials are expected (using line-of-sight analyses) to be visible within 650 m distance, primarily located upslope, from any landing point on the east mound
- Highest priority obs collected between lunar dawn and noon



Blocks & Outcrops Map in Yellow



Topography in 2.5 m intervals

Marius Hills – Volcanic Diversity

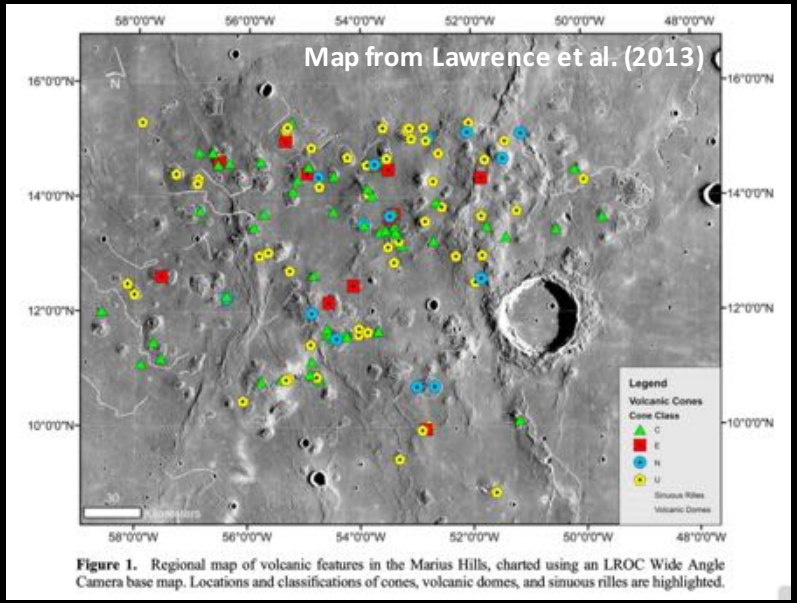
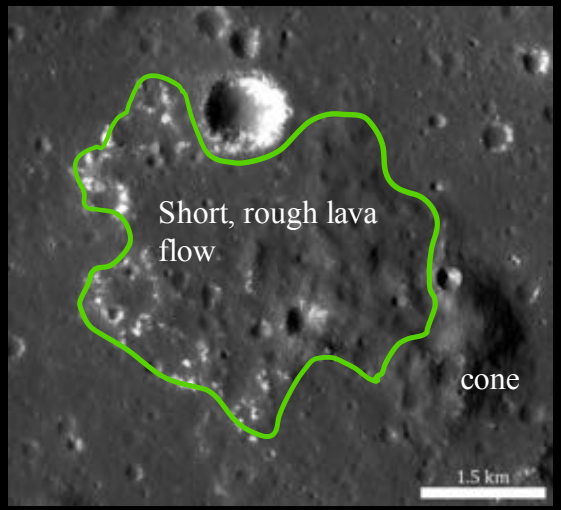


Figure 1. Regional map of volcanic features in the Marius Hills, charted using an LROC Wide Angle Camera base map. Locations and classifications of cones, volcanic domes, and sinuous rilles are highlighted.



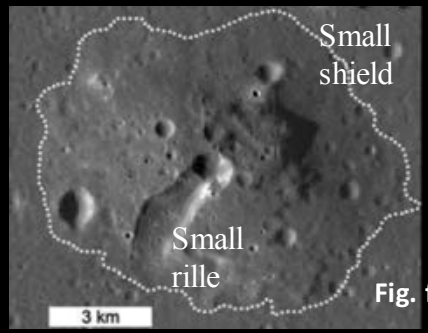
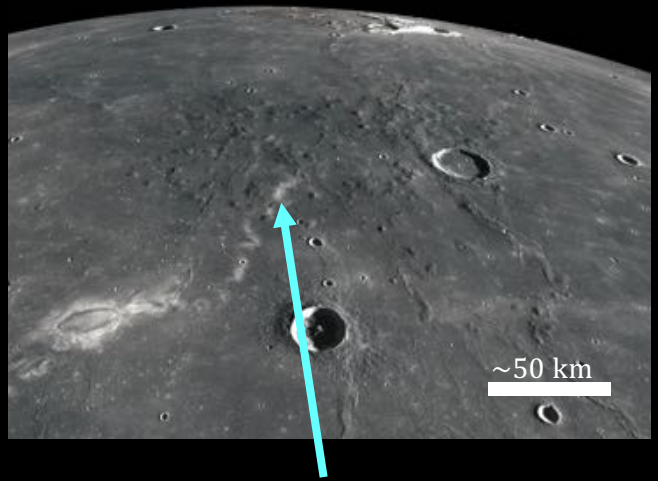


Fig. from Lawrence et al. (2013)

What we know:

- The densest regional concentration of volcanic cones, small shield volcanoes, and rilles on the Moon
- Superposed on a broad shield structure (Spudis et al. 2013)
- Eruptions may have occurred 3.5 to 1.2 Ga (Hiesinger et al. 2016)

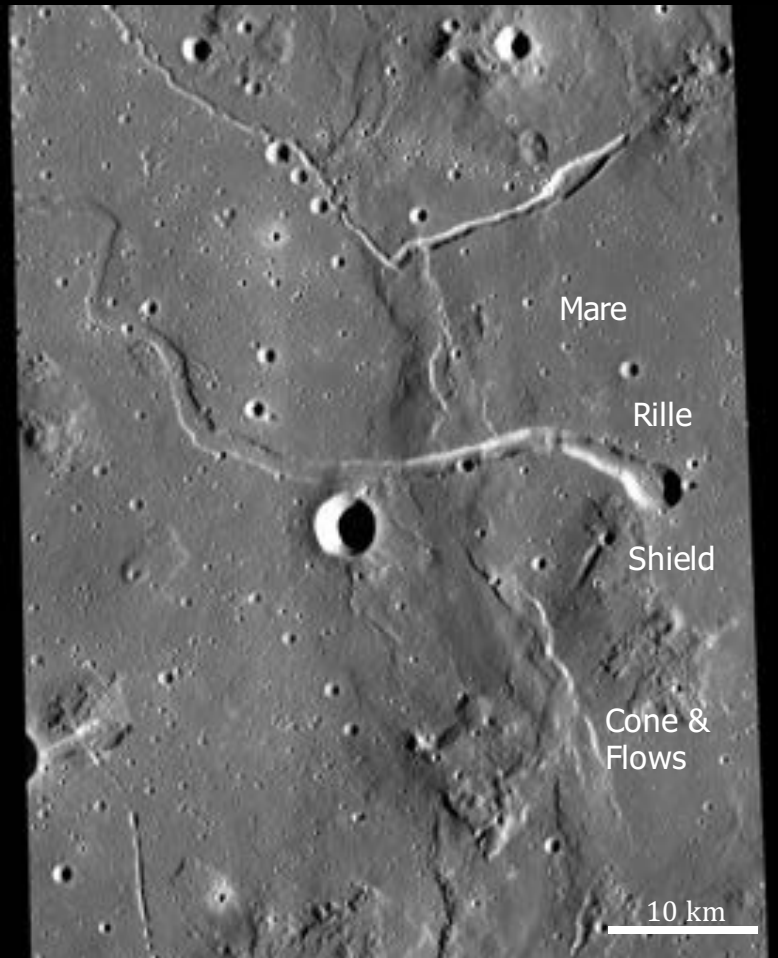
Marius Hills – Traceability & Science Objectives



Bonus objective: Reiner Gamma crosses part of the Marius Hills

Traceability to Goals	Science Objective	Key Measurements
Investigate range, flux, and diversity of basaltic volcanism (Decadal, SCEM, NASA's strategic plan)	What is the span of ages of eruptions across the MH?	• Compositional information across the shield to assess heterogeneity and possible evolution of deposits • In situ age dating • Sample return of selected materials to fully assess minor variations in composition or ages across the shield
	What are the compositions of the eruptions, and did they evolve over time/laterally?	
	Did the volatile content and eruption style evolve over time/laterally?	
	Did the eruption rates and sources vary over time/laterally?	
	What are the implications for the evolution of lunar volcanism and magma production and eruption mechanisms?	

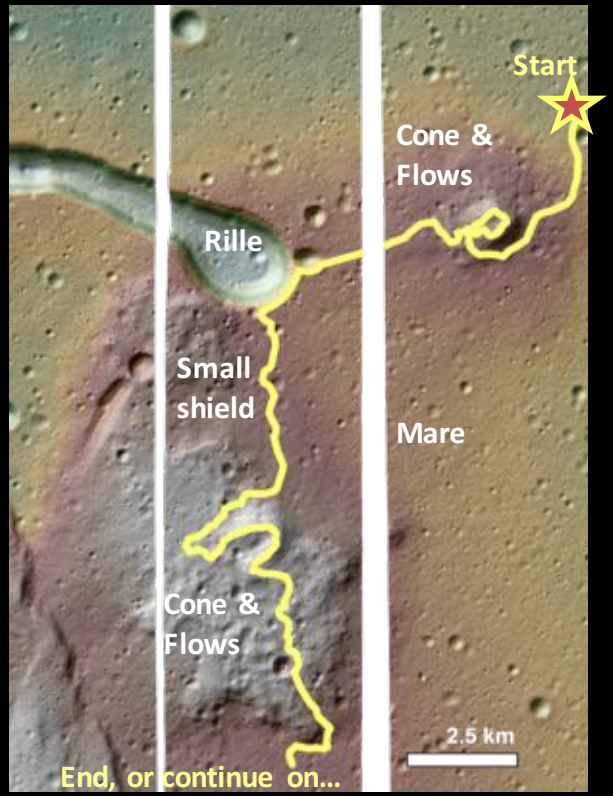
Marius Hills – Case for a Regional Rover



A Regional MH Rover Architecture

- A rover capable of traversing many kilometers and lasting through several lunar nights would provide insight into a broad sampling of lava flows and constructs
- Mobility allows determinations of eruptions that may span a broad range of ages and compositions from early mare to late-stage sputters
- However, sample return of selected materials would permit more detailed assessments of compositions and ages

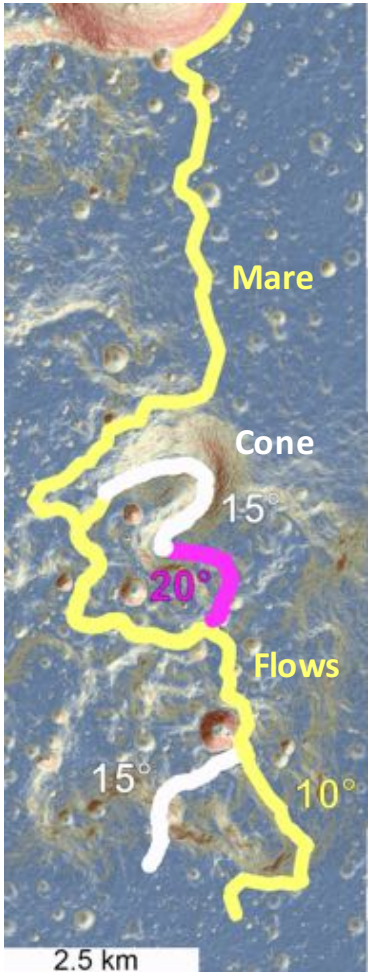
Marius Hills – Traverseability



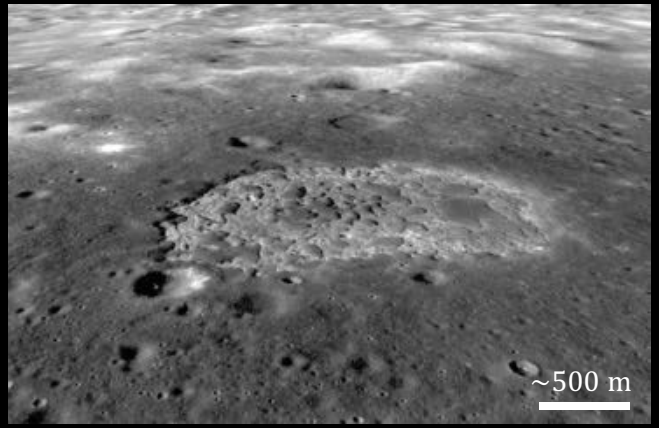
LROC NAC DTM, Colorshade Relief (2 m/p)

- Traverseability studies (in progress) of the MH using 2-m scale NAC topographic products have explored the possibility of roving across parts of this region (e.g., Stopar et al. 2016)
- These studies show that some landforms, particularly the steep-sided cones and flows, would require a rover than can handle slopes >20° in order to fully access
- However, in many cases navigating 10-15° slopes would be sufficient to traverse and sample key landforms and outcrops

Traverse Options
Slopemap (2 m/p)



Two fascinating mare sites that we can visit!



Ina Caldera

- Short-duration, pin-point mission (lander)
- Primary science objectives: mare basaltic magma *production* and evolution over time, investigate some of the youngest deposits on the Moon!

Marius Hills Volcanic Complex

- Regional roving, many km traversing
- Primary science objectives: mare basaltic magma *eruption mechanisms* and evolution over time; investigate one of the largest shield eruptions on the Moon!